Distributed MPC for a formation of mobile platforms: an experimental validation

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1 Introduction

Boosted by enhancements in communication technologies and computational power, networked multi-vehicle systems have received increasing attention over the last decades. A particular application hereof is formation control of multi-vehicle systems, which forms the basis for applications such as cooperative transportation by small automated guided vehicles or cooperative surveillance. This work presents an experimental validation of a previously presented Distributed MPC (DMPC) scheme [1] on a formation of three in-house developed robotic platforms.

2 Distributed MPC

The considered multi-vehicle optimal control problem (1) searches for each vehicle's time-dependent trajectory $\mathbf{x}_i(\cdot)$. Optimal trajectories are obtained by minimizing the sum of all vehicles' objectives J_i while respecting state and input constraints h_i, which include collision avoidance constraints. In addition the vehicles should move in formation. This is enforced by constraints $g_{i,j}$ which imply relations between the trajectories $\mathbf{x}_i$ and $\mathbf{x}_j$ of respectively a vehicle i and its neighbor j.

$$\begin{aligned}
\underset{\forall i:\, \mathbf{x}_i(\cdot)}{\text{minimize}} \quad & \sum_{i=1}^{N} J_i(\mathbf{x}_i) \\
\text{subject to} \quad & h_i(\mathbf{x}_i(t)) \geq 0\,, \\
& g_{i,j}(\mathbf{x}_i(t), \mathbf{x}_j(t)) = 0, \quad \forall j \in \mathcal{N}_i \\
& \forall t \in [0,T], \quad \forall i \in \{1,\ldots,N\}\,.
\end{aligned} \tag{1}$$

In [1] a DMPC strategy is proposed to solve problem (1) efficiently. The approach is based on two main ingredients. First, the multi-vehicle problem is decoupled such that the computational load can be distributed over the agents. This is achieved by applying the Alternating Direction Method of Multiplier (ADMM). In order to reduce the amount of communication, an updating scheme is proposed that solves only one ADMM iteration per control update. Second, a spline parameterization for the vehicles' motion trajectories $\mathbf{x}_i(\cdot)$ and a related enforcement of constraints on these trajectories allow an efficient reformulation of an agent's local subproblem.

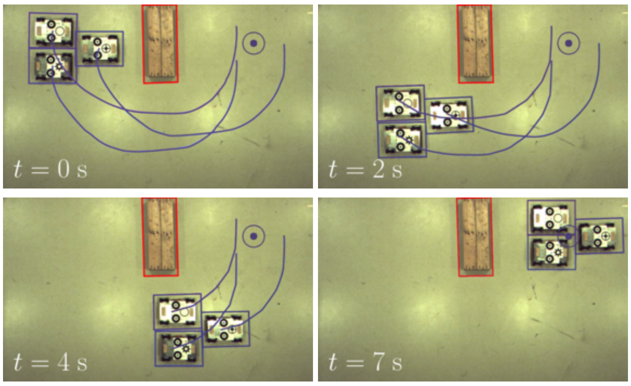

Figure 1: Experimental validation of the DMPC approach on a formation of robotic platforms moving in an obstructed environment.

3 Validation on mobile platforms

The DMPC approach is implemented and validated experimentally on three in-house developed robotic platforms. Each platform is equipped with four independently driven Mecanum wheels, which renders the system holonomic. The platform contains an Odroid XU4 single board computer on which the DMPC algorithm is implemented. The platforms' hardware communicate with each other over WiFi. The setup also includes a ceiling camera which detects obstacles in the environment and the platforms' absolute position and orientation. Each robot merges this information with its local encoder measurements for retrieving a fast and accurate state estimate. Figure 1 illustrates an example of a triangular formation avoiding an obstacle. The DMPC iterations are performed periodically with a rate of 4 Hz and generate state and input trajectories that are provided as reference to a low-level feedback controller running at 100 Hz.

References

[1] R. Van Parys and G. Pipeleers, "Online distributed motion planning for multi-vehicle systems," in *Proceedings of the 2016 European Control Conference*, pp. 1580–1585, July 2016.

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